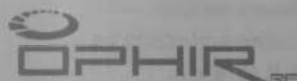


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ESD Help Desk

Provided by the ESD Association

Understanding the Resistivity of Materials

Knowing the resistance ranges for different types of materials is critical to solving ESD problems.

Q: What are the resistance ranges for conductive, static dissipative, electrostatic shielding, insulative, and anti-static materials?

A: For ESD purposes, many materials are classified by their resistance or resistivity characteristics. The following ranges and definitions are found in ESD Association or EIA standards publications.

Conductive materials are defined as those having a surface resistivity less than $1 \times 10^5 \Omega/\text{sq}$ or a volume resistivity less than $1 \times 10^4 \Omega\text{-cm}$.¹ With a low electrical resistance, electrons flow easily across the surface or through the bulk of these materials. Charges go to ground or to another conductive object that the material contacts or comes close to.

Dissipative materials have a surface resistivity equal to or greater than $1 \times 10^5 \Omega/\text{sq}$ but less than $1 \times 10^{12} \Omega/\text{sq}$ or a volume resistivity equal to or greater than $1 \times 10^4 \Omega\text{-cm}$ but less than $1 \times 10^{11} \Omega\text{-cm}$.² For these materials, the charges flow to ground more slowly and in a somewhat more controlled manner than with conductive materials.

Electrostatic shielding materials have a conductive layer with a surface resistivity of less than $1 \times 10^4 \Omega/\text{sq}$ or a vol-

ume resistivity of less than $1 \times 10^3 \Omega\text{-cm}$ per millimeter of thickness.² For ESD-sensitive devices, these materials provide Faraday cage protection from energy transfer.

Insulative materials are defined as those having a surface resistivity of at least $1 \times 10^{12} \Omega/\text{sq}$ or a volume resistivity of at least $1 \times 10^{11} \Omega\text{-cm}$.¹ Insulative materials prevent or limit the flow of electrons across their surface or through their volume. Insulative materials have a high electrical resistance and are difficult to ground. Static charges remain in place on these materials for a very long time.

Antistatic materials are not defined by resistance or resistivity. Antistatic refers to the property of a material that inhibits triboelectric charging. A material's antistatic characteristic is not necessarily correlated with its resistivity or resistance.²

References

1. ESD-ADV 1.0-1994, "Glossary of Terms," ESD Association, Rome, NY.
2. EIA-541, "Packaging of Electronic Products for Shipment," Electronic Industries Alliance, Arlington, VA.

Material Type	Surface Resistivity (Ω/sq)	Volume Resistivity ($\Omega\text{-cm}$)
Conductive	$< 1 \times 10^5$	$< 1 \times 10^4$
Dissipative	$\geq 1 \times 10^5, < 1 \times 10^{12}$	$\geq 1 \times 10^4, < 1 \times 10^{11}$
Electrostatic shielding	$< 1 \times 10^4$	$< 1 \times 10^3$
Insulative	$\geq 1 \times 10^{12}$	$\geq 1 \times 10^{11}$
Antistatic	Not correlated	Not correlated

Table I. Resistance ranges for materials.

To submit your questions to the ESD Help Desk or to browse the archives of past questions and answers, go on-line at <http://www.ce-mag/esdhelp.html>. Information on the ESD Association may be found at <http://www.esda.org>. ■

Niels Jonassen

Useful Static Electricity

Most people are unaware of the important applications that are based on electrostatic principles.

The term *static electricity* most likely brings to people's minds such phenomena as nasty shocks, clinging clothes, dirty TV screens, exploding tankers, and, especially to the readers of this magazine, ruined electronic components and circuits (also known as ESD problems). And one must admit that when the talk in the electronics industry is about static electricity, it is rarely for its virtues, but rather because—almost without exception—it presents itself as a nuisance or sometimes even as a risk.

This is slightly unfair to static electricity, although understandable considering that most people know only of its negative characteristics. Most people are unaware that static electricity—or rather, electrostatic principles—are vital for painting the refrigerator, the quality of sandpaper, the functioning of the photocopier and, even more importantly, the cleaning of smoke from coal-fired power plants. These are only a few examples of important applications of static electricity.

It may at first sight seem funny that the cause of the apparently unpredictable and bothersome expressions of static may also be put to good use. But from a physicist's point of view, it is not surprising at all. Most applications of static electricity are related to the handling of particulates, whether airborne

or suspended in liquid. The following characteristics are common to electrostatic processes:

- The force from an electric field on a small, charged particle may be much larger than gravity.
- It is very easy to monitor the electric force by monitoring the electric field.
- The electric forces acting upon airborne particles interfere insignificantly with the air and its movement.



Niels Jonassen

In all electrostatics applications, some materials must be electrified, meaning they must be able to respond to an electric field. This can be done either by giving the materials a net charge or by exposing them to induction or polarization.^{1,2} The three most significant electrification processes are corona electrification, contact and triboelectrification, and induction and polarization in an electric field. Precipitation uses corona electrification. Often, two or more electrification processes are active. For example:

- Separation uses both corona and triboelectrification.
- Surface treatment uses contact and triboelectrification and polarization.

This article focuses on examples of all three of these applications.

Precipitation

The principle of electrostatic precipitation is the charging of airborne (solid or liquid) particles with the same polarity, which consequently makes them move in the same direction in an electric field.

Many industrial processes produce airborne particulates to such an extent that it is necessary to clean the affected air before releasing it into the environment. A prime example is the production of fly ash in coal-fired electric power generation. A lot of other industries also produce particulate air pollution on a large scale.

Even everyday activities, such as cooking and cleaning (not to mention smoking) produce a particle concentration in the air, often at unacceptable levels. Although particulates can be removed from the air by mechanical filters, for industrial pollution, the world would be at a loss without electrostatic precipitation, usually in the form of the electrofilter.

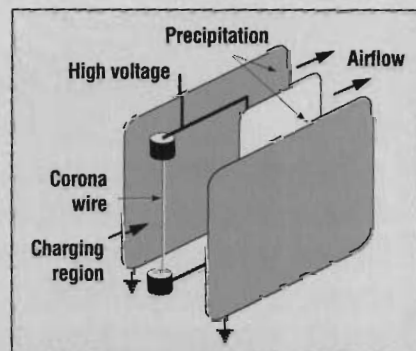


Figure 1. Overview of an electrofilter.

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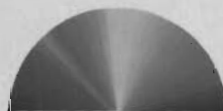


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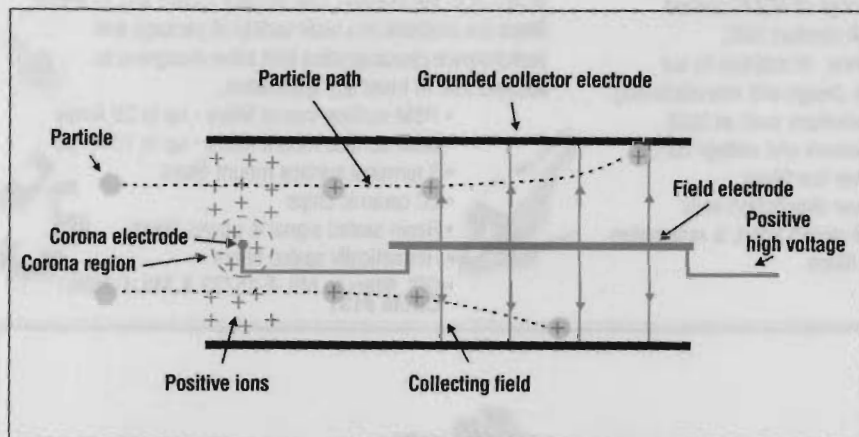


Figure 2. Electrofilter, working principle.

The electrofilter is the oldest application of static electric principles to be put to industrial use, dating back to 1906 when Frederick Cottrell built his first precipitator. Figure 1 shows a simplified drawing of an electrofilter, and Figure 2 illustrates its working principles.

A single corona wire (or series of them) is kept at a high potential, which causes positive and negative ions to be

formed within a thin sheath around the wire. In the figure, the negative ions are attracted to the wire where they are neutralized. The positive ions, however, move toward the grounded electrodes, forming a highly concentrated region of positive ions. When the dirty air is drawn through this region, the ions will tend to attach to particles in the air.

The airflow carries the charged parti-

cles into the precipitation volume, where they move toward the collecting electrodes and where, eventually, they may plate out. Whether a particle will actually land on the collecting electrodes depends on many factors, including flow rate, particle size, particle charge, filter dimensions, and field strength.

Several methods can be used to remove the plated-out materials from the collecting electrodes. For industrial plants, big mechanical shakers may be needed for cleaning; for household electrofilters, it may be sufficient to place the filter unit in the dishwasher every other week to remove lingering particulates.

Separation

The principle of electrostatic separation is the charging of components in particulate mixtures with opposite polarities (or leaving conductive materials uncharged) and subsequently separating the components by mutual repulsion or by an external electric field, possibly aided by gravity.

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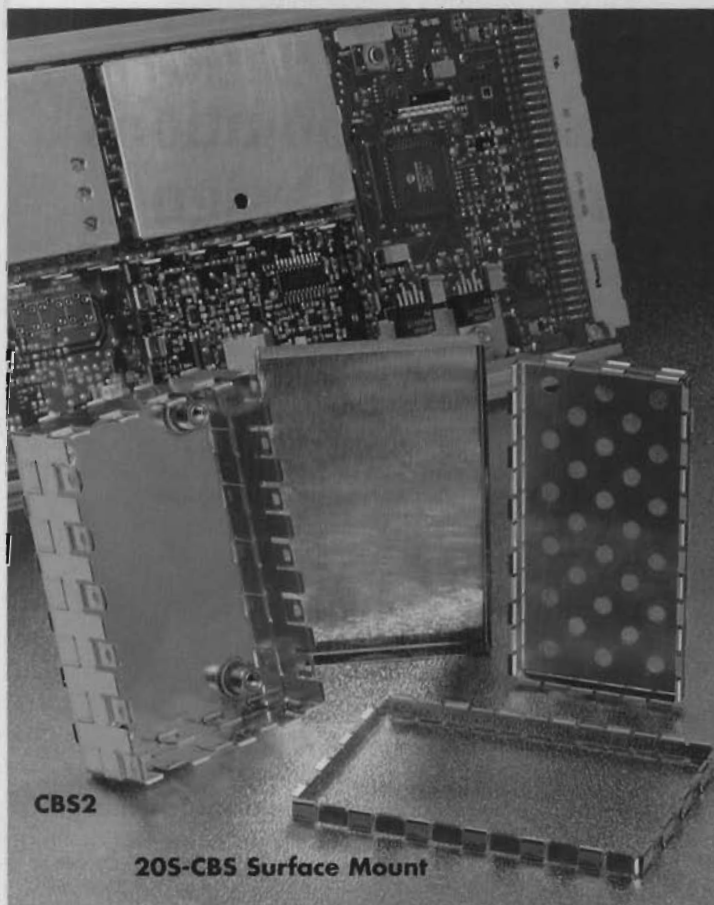


Figure 3 depicts this process using a drum separator. A mixture of conductive and insulative particles is fed from a hopper onto a grounded drum, and all the particles are charged (positively in the case shown) by a corona discharge. When the particles leave the corona region, the conductive particles lose their charge to the drum and move away by gravity and "centrifugal" forces. The insulative particles stick to the drum until a brush or scraper, possibly assisted by an ac corona discharge, removes them.

The charging of the particles to be separated can be achieved using a variety of methods. Selecting the appropriate method depends on several factors, including the properties of the materials themselves, the state of their surfaces, and external parameters such as electric fields and temperature gradients across interfaces. Table I lists a few of the many material mixtures that in particle form can be separated electrostatically to produce a commercial benefit.

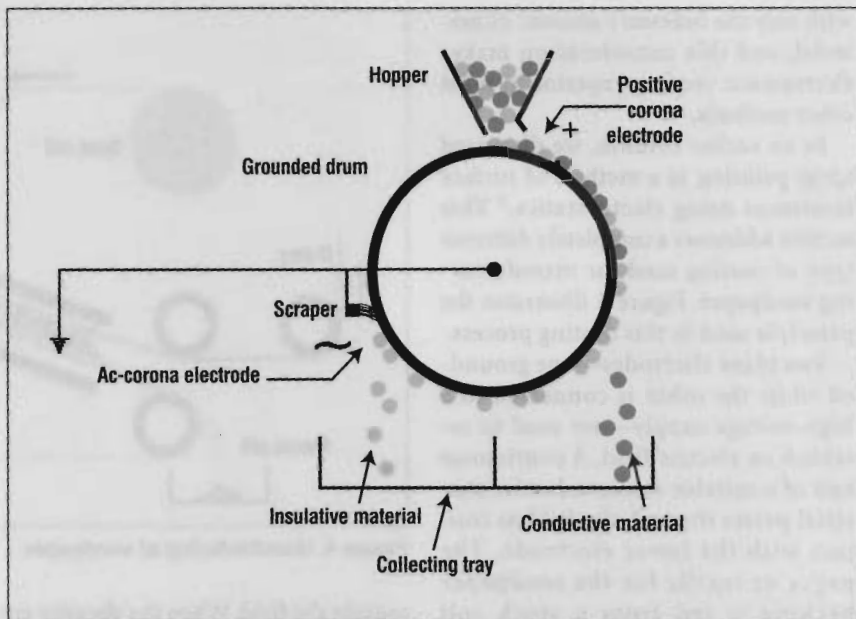


Figure 3. Electrostatic drum separator.

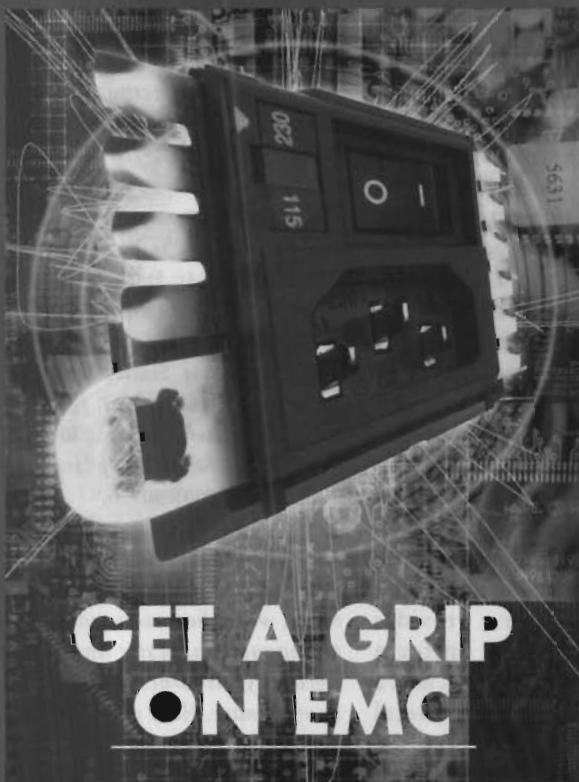
Coating

Nearly all products manufactured today are coated in some way. This is true for the paper we write on, the

clothes we wear, the cars we drive, and the furniture we sit on. For practical, economic, and environmental reasons, it is desirable that products be coated

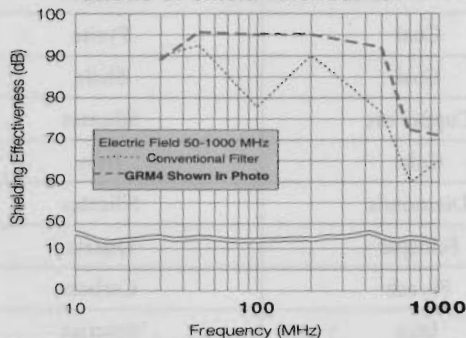
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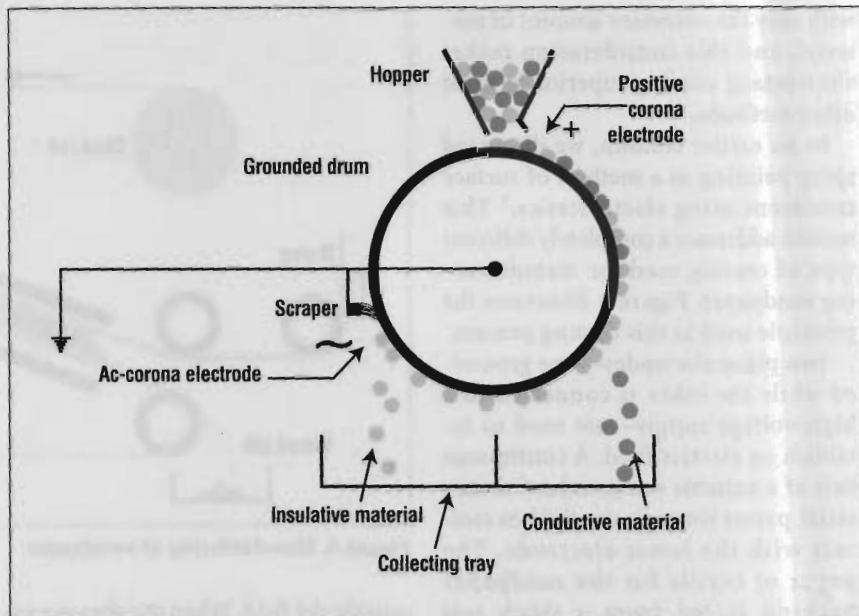


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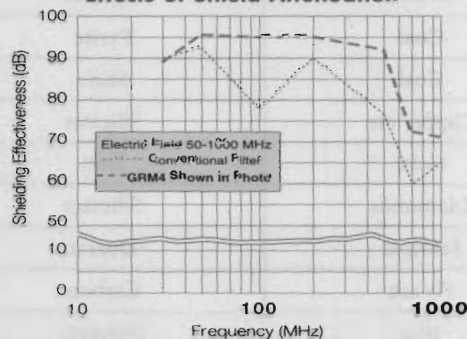
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with only the necessary amount of material, and this consideration makes electrostatic coating superior to most other methods.

In an earlier column, we discussed spray painting as a method of surface treatment using electrostatics.³ This section addresses a completely different type of coating used for manufacturing sandpaper. Figure 4 illustrates the principle used in this coating process.

Two plane electrodes—one grounded while the other is connected to a high-voltage supply—are used to establish an electric field. A continuous belt of a suitable semiconductive material passes through the field in contact with the lower electrode. The paper or textile for the sandpaper backing is fed from a stock roll through the field, in contact with the upper electrode. Before the paper enters the field, a layer of adhesive is applied to the side of the paper that will eventually face downward.

An abrasive such as ground agate is fed from a hopper onto the lower belt

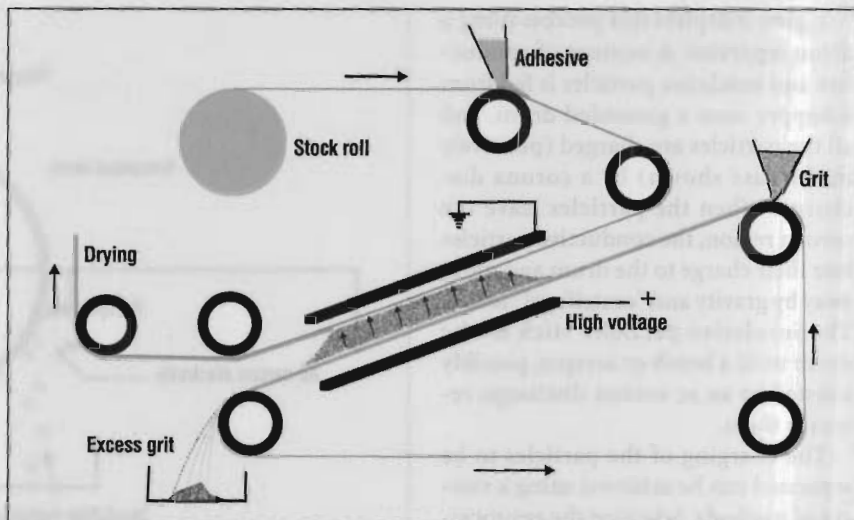


Figure 4. Manufacturing of sandpaper.

outside the field. When the abrasive enters the field, the polarized grains will be charged directly with the same polarity as the lower electrode.

The grains will align their longest axes with the field, and when the field strength is high enough, they will move toward the upper electrode and embed themselves in the adhesive with a sharp tail protruding. If a grain hits a point already occupied by another grain, the late arriver is neutralized, charged with the opposite polarity, and repelled. It will then fall to the lower belt, repeating the process.

When the grit-covered face leaves the field, a shaker removes loose material and a drier sets the adhesive. The electrostatic deposition of the abrasive provides a more uniform distribution and a more beneficial orientation of the single grains than is possible by a purely mechanical process.

Conclusion

The three topics treated here are only a few of many useful applications of electrostatic principles. Equally valuable applications include electret microphones and filters, electrostatic motors, and the vital field of electrostatic image forming known as xerography, without which we wouldn't have photocopies. The purpose of this short survey is to provide an overview of the possibilities of electrostatics. Perhaps the next time you are frustrated by an ESD problem, you might even remember that static electricity can also be looked at as a good thing.

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2. Niels Jonassen, "Polarization, for Better or Worse," in *Mr. Static, Compliance Engineering* 17, no. 5 (2000): 34-40.
3. Niels Jonassen, "Is Static Electricity Static?," in *Mr. Static, Compliance Engineering* 17, no. 1 (2000): 30-36.

Niels Jonassen, MSc, DSc, worked for 40 years at the Technical University of Denmark, where he conducted classes in electromagnetism, static and atmospheric electricity, airborne radioactivity, and indoor climate. He is now officially retired and divides his time among the laboratory, his home, and Thailand, writing on static electricity topics and pursuing cooking classes. He can be reached at mr.static@scientist.com. ■

Material A	Material B
Asbestos	Silicates
Coal	Pyrite
Coal	Shale
Copper ore	Silicates
Coke	Iron
Diamonds	Silicates
Feldspar	Quartz
Fly ash	Carbon
Iron	Silicates
Kaolin	Iron contamination
Limestone	Silicates
Nickel	Copper ore
Zirconium	Sand
Barley, rice	Rodent excrement
Cocoa beans	Shells
Cotton seeds	Stems
Grain	Garlic seeds
Nut meat	Shells
Photographic film	Paper
Polyvinyl	Polyester

Table I. Electrostatically separable mixtures.